Optimizing a highly-accelerated FatNav for high-resolution motion-correction

Daniel Gallichan[1], José P Marques[2], and Rolf Gruetter[1,3]

[1]*CIBM, EPFL, Lausanne, Vaud, Switzerland,* [2]*Dept. of Radiology, University of Lausanne, Vaud, Switzerland,* [3]*Depts. of Radiology, Universities of Lausanne and Geneva, Vaud, Switzerland*

Introduction: We recently demonstrated that the natural sparsity of MR acquisitions with a fat excitation allows high-resolution motion-navigator acquisitions (FatNavs) to be acquired with very high acceleration factors which can be used to correct for the small motion of compliant healthy volunteers (<1mm and <1°) during high-resolution structural scans [1]. The previous work used a 3D-GRE FatNav of 2mm isotropic resolution and 8×8=64 times GRAPPA acceleration [2]. In this study we aim to test the accuracy and precision of FatNavs at different nominal resolutions and acceleration factors.

	Resolution	Acceleration	TR_{volume}
P1	2mm	8×8=64	288 ms
P2	3mm	6×6=36	231 ms
P3	4mm	4×4=16	288 ms
P4	5mm	2×2=4	528 ms
P5	6mm	2×2=4	288 ms

Table 1: Navigator parameters.

Method: Imaging was performed on a 7T head-only Siemens MR scanner with a 32-channel RF coil (Nova Medical Inc.). 4 healthy adult volunteers were each scanned for a period of 10 minutes, during which time alternating 3D-GRE volumes with either a binomial fat excitation or binomial water excitation were acquired. Each volume had the same imaging parameters: 2mm isotropic resolution, 88×128×128 matrix, TE/TR = 1.35/3.0 ms, BW = 1950 Hz/Px, FA = 5°, GRAPPA 2×2=4 (integrated 16×16 calibration lines), ¾ partial Fourier acquisition in both PE directions, TR_{volume} = 5.2 s. The subjects were instructed to remain still during the scan, but in order to induce small movements during the short scan which correspond to the range of movements expected during a longer scan, an air-cushion under the subject's head was slowly deflated by 60 ml during minutes 3 to 6, and then reflated during minutes 6 to 9. Data were retrospectively discarded to simulate acquisitions at various resolutions and GRAPPA acceleration factors chosen to have approximately similar acquisition times, with a separate fully sampled volume (TR_{volume}=32s) used as the separate calibration lines to allow shorter nominal TR_{volume} for each navigator. The parameters used are shown in Table 1. For each set of navigator parameters, reconstructed images were co-registered (rigid-body) using SPM *realign* [3] and the 6 estimated motion parameters compared to the 'true' motion (taken as the motion parameters estimated from the original 2mm, 2×2 accelerated data for water or fat respectively). As translations in mm exhibit a similar range to rotations in mm, bias and RMS error were assessed for each parameter separately, then averaged across all parameters and all subjects for each set of navigator parameters. 'Bias' was defined as the absolute value of 1-{*slope of the linear regression of estimated motion parameters compared to 'true' motion*}. 'RMS error' was defined as the RMS of the residuals of this regression.

Results and Discussion: In agreement with previous results [1,4], fat images were considerably more robust to undersampling artifacts at very high acceleration factors (Fig. 1a shows images at 8×8=64 times acceleration). However, comparison of the estimated motion parameters at this acceleration factor to the 'true' motion shows a consistent underestimation (bias) in the motion-parameters. Visual inspection of reconstructed images in the time-series suggests that the use of separate ACS data led to (visually) minor artifacts following head-movement which led to underestimated motion parameters. Figure 1d shows that navigator parameters P3 (4mm, 4×4=16) give the lowest bias in estimated motion parameters – both for FatNavs and WaterNavs. The RMS error is similar for navigator parameters P1, P2 and P3 for the FatNavs – but the increased bias of P1 and P2 vs P3 would suggest from this data that P3 would be the best choice of navigator parameters. For all navigator parameters the FatNavs gave smaller biases and lower RMS errors than the WaterNavs.

Conclusion: Very highly accelerated FatNavs give more accurate and more precise motion-parameters than WaterNavs acquired with the same parameters – as the sparse fat image leads to fewer acceleration artifacts. With the chosen image registration pipeline and constraints on the total acquisition time the best choice of FatNav parameters is 4mm resolution, 4×4=16 times acceleration – resulting in low bias and low RMS error in a 288ms navigator. Future work will investigate the possibility of increasing further the temporal resolution (under 100ms) and of dynamically updating the GRAPPA weights to avoid the observed underestimation of the motion parameters.

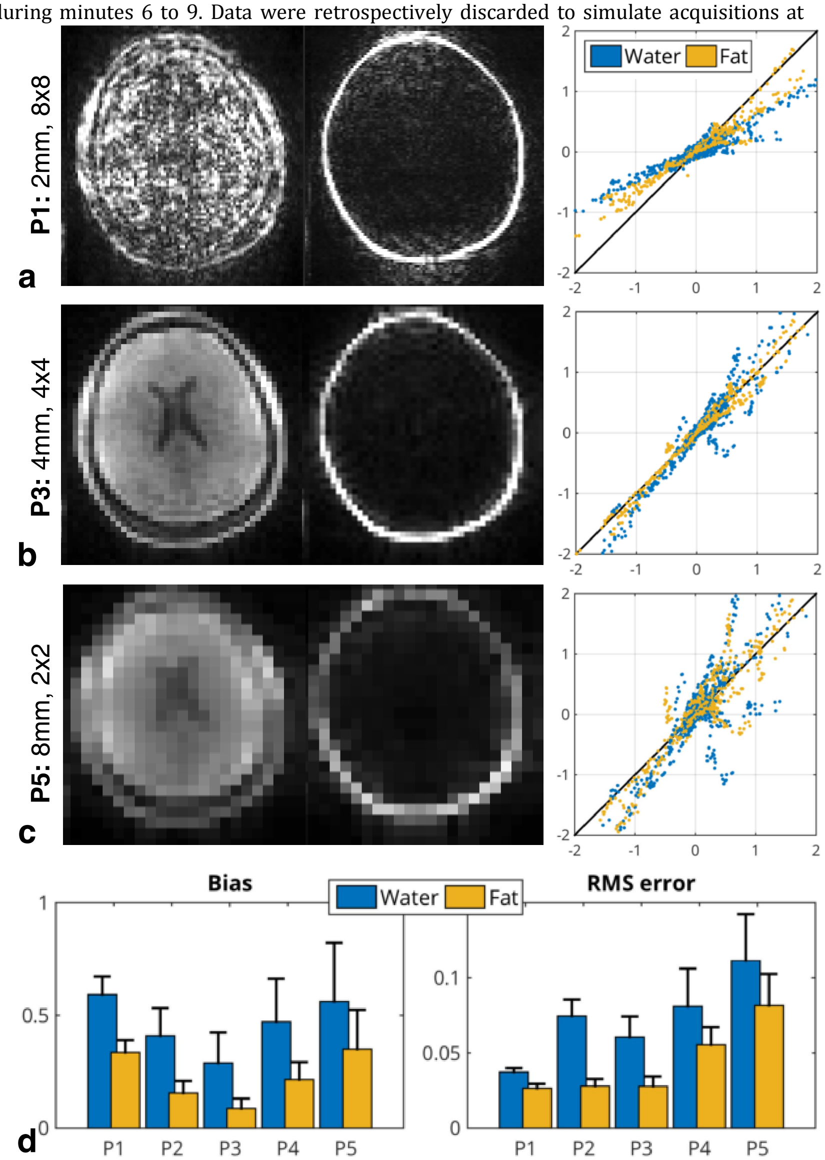

Figure 1: (a-c) Water and fat images for navigator sets P1, P3 and P5 alongside estimated motion parameters (mm or °) compared to the 'true' motion. **(d)** Bias and RMS error in estimated motion parameters for each set of navigator parameters.

[1] Gallichan et al, Proc. ISMRM 2014, p4345; [2] Griswold et al, MRM (2002) 47:1201-1210; [3] www.fil.ion.ucl.ac.uk/spm; [4] Skare et al, MRM (*Early view online*)

This work was supported by CIBM of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations, as well as SNSF project number 205321_153564.